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ECHO Development Notes

edited by Dawn Berkelaar and Tim Motis

INSECT PEST MANAGEMENT: OPTIONS FOR MONITORING

This article explains some principles and practices for conducting in-field observations (sampling) to inform pest management decisions.

APIOS AMERICANA

Apios americana *is a climbing, perennial vine and a member of the legume (Fabaceae) family. It is well-suited for small plantings around the home, producing protein-rich tubers that can be cooked in multiple ways.*

AGROFORESTRY DESIGN TOOL™ REVIEW

The Permanent Agriculture Resources and Forest Agriculture Research Management Center, led by Craig Elevitch, recently released their Agroforestry Design Tool™. This article reviews the tool.

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ECHO
17391 Durrance Road
North Fort Myers, Florida 33917
USA

Insect Pest Management: Options for Monitoring Pest Populations

by Annie Deutsch and Stacy Swartz

Part 2 of 4 in a series about Integrated Pest Management (IPM)

Insect pests affect all forms of agricultural production, from densely planted field crops to high-value nursery plants to grains in storage. A pest management plan should start with foundational knowledge about local pest species and careful planning for pest prevention. We highlighted pest prevention strategies in the first article of this IPM series [http://edn.link/i]. After taking precautionary measures specific to your region and implementing practices that prevent pests from entering or multiplying in your production area, you will need to keep a watchful eye on pest populations and intervene before insect pests are likely to cause too much crop damage, or when they already are causing damage. This article explains some principles and practices for conducting in-field observations (sampling) to inform pest management decisions (Figure 1). The next article in this series will discuss intervention options and a final article will explain evaluation and assessment of intervention efforts as well as the cycle of IPM improvement.

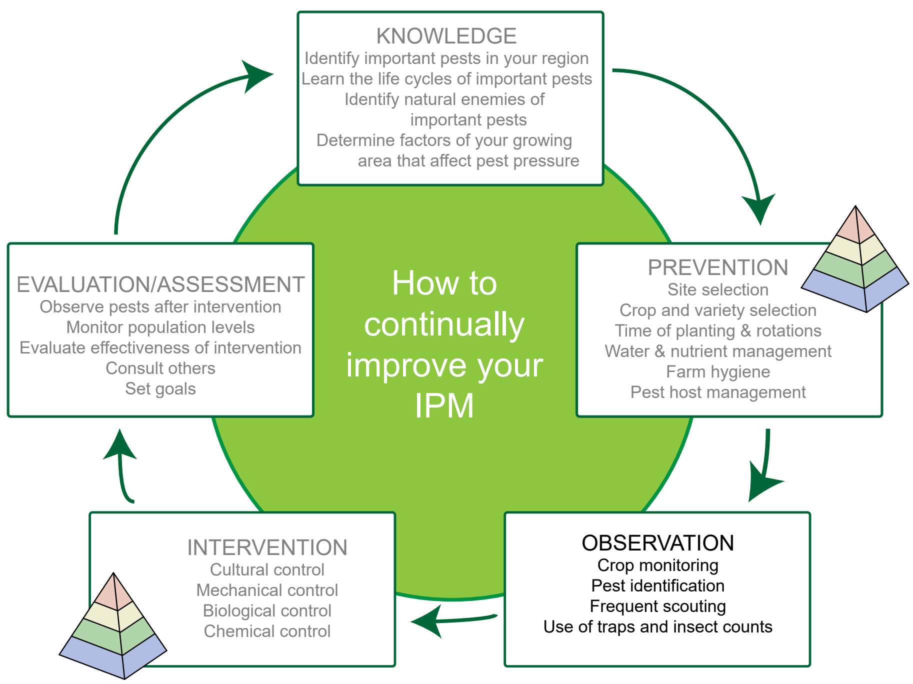

Figure 1. Stages of an example IPM cycle. Planning can start at any stage of the cycle, and the order of stages is flexible. The pyramid icon indicates strategies that prevent or suppress insect pests. *Source*: Adapted from farmbiosecurity, Creative Commons Attribution 3.0 license

Potential Constraints

Smallholder farmers face several hurdles that make it difficult for them to observe agricultural pests. Some farmers who have fields that are far from their home may only travel to the field for important management activities such as planting, weeding, and harvesting. This limited time in the field is sometimes insufficient to catch pest populations at levels that can be controlled in a timely and effective manner. Farmers may be unable to scout fields often enough without using valuable resources (e.g., time and travel expense).

Generally speaking, little information exists on the topic of pest management using locally available resources in tropical environments. Temperature and crop species (plant host of the pest) affect the life stage length of many pests (e.g. Nava-Camberos, *et al.* 2001 [1]). A shorter life cycle means an insect pest species can go through multiple generations and can multiply rapidly. However, little is known about how in-field tropical conditions affect pest life cycles. Also, little research has been done to better understand alternate tropical host species of many of the major agricultural pests and diseases.

When it comes to insect pest management, look for local sources of expertise. Regional agricultural universities, government agencies, or agricultural organizations may host local extension services. Trained professionals may be able to help with pest identification, early detection, and scouting practices proven to be effective in the region.

[1] Life stages generally cycle faster in warmer temperatures (up to a point) and therefore, life stages are shorter and populations with enough resources can multiply faster. Nava-Camberos *et al.* (2001) found that life spans of silverleaf whitefly (*Bemisia argentifolii*), on cotton and cantaloupe, were an average of 21 days shorter at 30°C than 20°C.

Seek out these professionals' local expertise and knowledge before taking more general approaches, such as those outlined in this article. If your area lacks such experts, you may need to depend on information or techniques that have been utilized for adjacent or similar situations.

Constraints such as the ones described in this section will shape how insect observation is practiced locally. The remainder of this article outlines general principles and practices for detecting, identifying, and monitoring pest populations, in order to inform next steps.

Observation

Globally, roughly 1 million insect species have been named. Scientists estimate that over 5.5 million more species exist but have yet to be discovered (Stork, 2018). The vast majority of insect species are beneficial or have little impact on crop production or human activity. However, a small portion (perhaps only 1% of insect species) are considered pests (Omkar, 2018). Currently, the most severe agricultural pests are non-native species that were introduced and spread through a region, for example through the import and export of agricultural products, in/on plant material, in soil, or through severe weather events. Natural predators that would otherwise keep their populations in balance may not be present outside of the insects' native areas. Sometimes, native insects that did not previously impact farmers' crops will switch host plants to new species that farmers start to grow; this can cause the insects to be elevated to pest status. However, please understand that the majority of insects do not damage crops. In fact, many are important parts of an integrated pest management plan because they help control outbreaks of other insect species.

When insects are present in low numbers, you may find it difficult to determine whether a particular insect is a crop pest. Pests are often defined based on their feeding behavior; how quickly they reproduce; whether or not they have natural enemies present; whether they transmit diseases to humans, livestock, or plants; and/or if they contaminate the final food product. Table 1 lists mouthparts and type of metamorphosis of insect orders that include common agricultural pests. The table also gives examples of insect species from each order. The kind of mouthparts and type of metamorphosis are helpful attributes to know

Table 1. Groups, mouthparts, type of metamorphosis, and specific examples of common insect pest orders.

Order	**Groups**	**Mouthparts**	**Metamorphosis**	**Example**
Coleoptera	beetles weevils	chewing	complete	Sweet potato weevil (*Cylas formicarius*)
Diptera	flies	sucking/piercing/lapping	complete	Mediterranean fruit fly (*Ceratitis capitata*)
Hemiptera	true bugs aphids planthoppers	piercing-sucking	incomplete	Painted leafhoppers (*Endria* sp.)
Lepidoptera	butterflies moths	chewing (immature stages)	complete	Fall armyworm (*Spodoptera frugiperda*) and tomato leafminer (*Tuta absoluta*)
Orthoptera	grasshoppers crickets	chewing	incomplete	Desert locust (*Schistocerca gregaria*)
Thysanoptera	thrips	rasping-sucking	complete (modified)	African thrips (*Ceratothripoides brunneus*)

about, because they can indicate where an insect pest might be found, the type of damage it might cause, and the best way to treat for it.

Insects' feeding behaviors depend on their mouthparts. Insects with chewing mouthparts remove pieces of leaf or fruit tissue, leaving holes in the plant. Because these insects typically ingest plant tissue, insecticides applied to the surface of the plant may be effective. By contrast, insects with sucking mouthparts do not feed on the outside of the plant, but rather consume sap from within the plant, killing plant cells. In this situation, plant damage can include leaf distortion, yellow stippling, or shriveled grains. Since insects with sucking mouthparts only feed on internal plant juices, insecticides applied to the surface of the plant will not be effective.

Figure 2. Insect webbing is a substance insects create that sticks leaves together. This photo is of southern beet webworm on amaranth. *Source*: Annie Deutsch

Metamorphosis describes the way an insect changes from an immature stage to an adult. In incomplete metamorphosis, immature insects look and act very similar to the adults. Insects that undergo complete metamorphosis go through a pupal stage where they change from one form to something completely different (e.g., a caterpillar turns into a butterfly). The immature stages of these insects typically look nothing like the adults, are often found in different locations, and can be much harder to identify. For example, many immature beetles live underground or tunnel into roots, but the adults live on the aboveground portion of the plant. Often an insect is only a pest at one stage of complete metamorphosis; many moths and butterflies do not feed as adults and can even be beneficial pollinators, but the caterpillars (immature/larval stage) can completely defoliate a crop. There will be exceptions to these categories, but understanding the basic ways insects feed and develop is critical for successful pest management.

Insect feeding damage, webbing (Figure 2), or other insect activity can look similar to many bacterial, fungal (Figure 3), or viral diseases or to plant nutrient deficiency symptoms. Before taking action against an assumed insect pest, verify that the symptoms you observe are

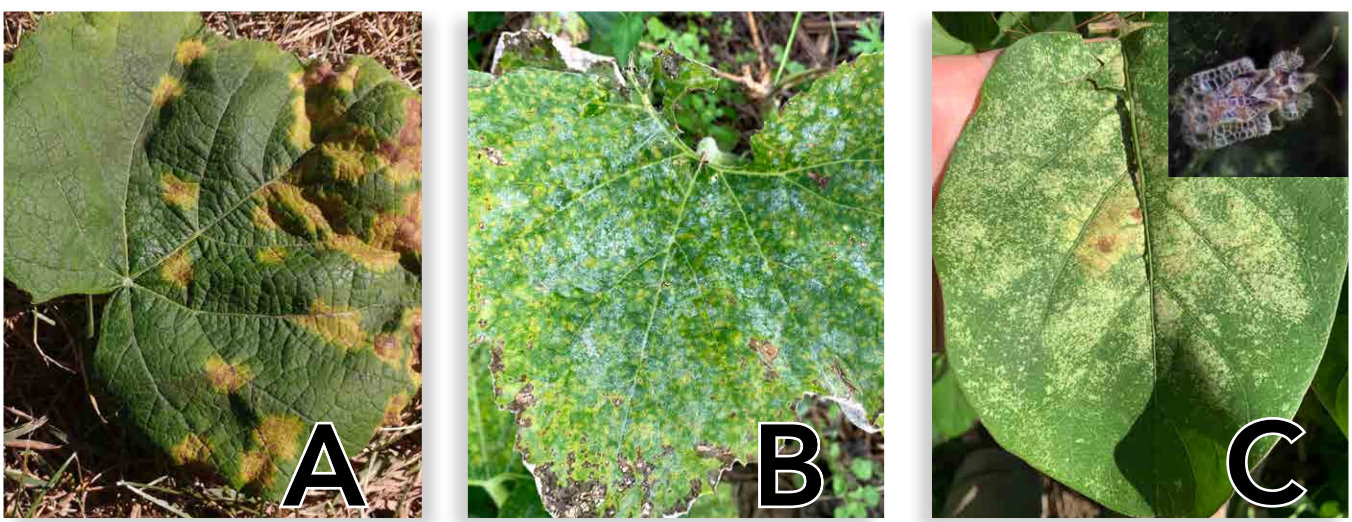

Figure 3. Leaf symptoms of fungal diseases, such as downy mildew (A) and powdery mildew (B), can look similar to damage from piercing-sucking insects. Downy mildew is restricted by leaf veins, giving it a blocky appearance with white fungal growth on the underside of the leaf. Powdery mildew has small circular discolorations across the whole leaf surface, often forming white spores on either surface of the leaf. Either of these can be confused with damage from piercing-sucking insects (C, lace bug damage on jack bean with lace bug photo inset), which cause pin-point discoloration where they have fed on the underside of the leaf. This can lead to brown necrotic spots that look similar to downy mildew. *Source*: ECHO Staff

not caused by a bacterial, viral, or fungal infection. Insecticides are not effective against these types of infections, and improper use of insecticides wastes farmers' valuable resources and can kill beneficial insects. For visual comparisons of common diseases and pest damage, view this resource [http://edn.link/photoi].

Sampling

The goal of scouting is to estimate the pest population within a field or garden, rather than to count or tally the entire insect population. This sampled estimate allows you to determine whether intervening to control the pest is worth the time, money, and potential negative impacts, or whether you should wait and continue to monitor the pest population.

You can sample for insects through active behaviors or through passive traps. For both methods, carefully consider where to sample; if you don't, the results might be meaningless. Insect populations vary in density throughout a field, so be sure to check multiple areas in a random pattern. Many insects will congregate in one area of a field but be present in much lower numbers elsewhere. If you only sample in the heavily infested area, you might think that the pest population is much greater than it actually is. If you sample elsewhere, you might make the opposite mistake of believing that insect levels are very low, when they are not. In general, the best way to actively sample is to walk an 'M' or 'W' pattern (Figure 4) throughout the field or garden, making 5 to 10 stops to inspect plants for insect presence or activity. For example, when scouting for fall armyworm in maize, it is recommended to make 5 stops in that pattern and inspect 20 consecutive maize plants at each stop. This allows for a random sampling that represents the entire field. When scouting, also pay attention to areas of the field that might have worse damage than others (e.g. field edges often have greater amounts of damage due to points of entry from surrounding areas). In these cases, you could use intervention strategies just in those areas but not the rest of the field. For more information about how to monitor, see *EDN* 136 [http://edn.link/insectmonitoring] (Liptak and Motis, 2017).

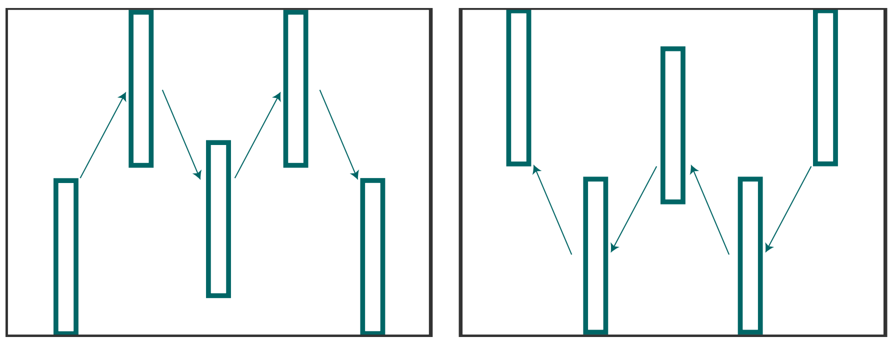

Figure 4. 'M' (left) and 'W' (right) sample pattern example. Each box would consist of several plants, each of which is inspected for insect presence or activity. *Source:* Stacy Swartz

Active Sampling

You can accomplish *active sampling* in a variety of ways. Sweep netting is one way to estimate an insect population throughout an entire field. To construct a basic sweep net from local materials, take a light-colored cloth sack, add a firm wire ring around the opening (30 to 38 cm diameter), and attach it to a stick or pole (Figure 5). Sweep nets work best for low-lying crops such as rice and other small grains, or non-vining beans before they flower and fruit—plants that are tough enough to handle the damage without losing fruit or too much leaf mass. Sweep nets also work best for insects that dislodge easily from the plants.

Figure 5. A sweep net made from a pillowcase, thick wire, bamboo, and rubber lashing.
Source: Annie Deutsch

Beating works well for plants that are too large for a sweep net. To use this technique, tap or shake individual branches over a tarp or sheet and record the number and kind of insects that fall down onto the tarp or sheet. Beating works best in cool temperatures in the early morning, when insects are more likely to fall off the branches than to fly away.

With the technique of population indexing, you indirectly measure the pest population by observing signs of insect damage. For example, you could estimate the percent leaf defoliation; amount of insect frass (feces); and/or occurrence of tents, nests, webs, emergence holes, or tunnels in fruit or stems. You could also listen for insect sounds, such as biting or chewing, to help you estimate potential insect damage.

As you scout for evidence of insect pests, be sure to gather and record data (including observations). The information will allow you to monitor changes in the insect population throughout the growing season; it can also help you know when to scout in following seasons. For an example of a scouting record sheet developed by the Canadian Foodgrains Bank, view this document [http://edn.link/faw]. Though originally used for fall armyworm, the resource can be adapted for other pests.

Some pests threaten regional food security. For these, resources may be available to monitor the spread, alert farmers, and create awareness throughout the community and region. Such resources should not replace active scouting in a particular field, but can help you know when to focus on scouting. Examples include the Fall Armyworm Monitoring and Early Warning System (FAMEWS) [http://edn.link/2gp74n] mobile app and Locust Watch [http://edn.link/6mzwhc] (for the desert locust). Both of these are available through the FAO.

Passive Sampling

Passive sampling typically includes the use of insect traps. Traps range from highly sophisticated and expensive pheromone traps to a container full of soapy water. When making a homemade trap, consider the color of the trap; how the insect will be trapped in or on the trap; and how often you plan to check the trap. As examples, you could use soapy water in colored pans or dishes (often yellow is the most attractive to insects; Figure 6); cards covered with a sticky material and then hung from a tree or placed on a stake in a field; or a pitfall trap made by burying a cup, so insects that walk on the ground fall inside. See this research blog post [http://edn.link/j4jfc2] for a comparison of these three types of traps deployed in a sorghum field at the ECHO Global Farm in Florida. Always add a bit of soap to traps containing water, to break the water's surface tension. Otherwise, insects are small enough that they will stay on the surface of the water and escape. To monitor night-flying pests such as moths, you might consider a light trap. Fruit or other attractants, like meat, can make a trap more effective or can even become the trap itself. For example, in temperate regions, when monitoring for apple maggot (a pest of apples), the trap is sometimes a red plastic ball covered in sticky material and sometimes an actual apple covered in sticky material. Note that these traps are intended to help you determine the pest's life stage, when they are active, and approximately how many are present. They are not designed to catch enough insects to provide control.

Figure 6. Farmer using old yellow, plastic container and motor oil (unused) to trap pests.
Source: Patrick Trail

If you are growing a high value crop, you may want to purchase laboratory-prepared pheromone lures or attractants (if available) to help you monitor for specific pests.

Intervention Thresholds

One of the hardest decisions you will need to make as a farmer is to determine when a pest population is high enough that you should intervene to control the population.

The upper damage boundary (also known as the economic injury level; Figure 7) is the point at which the profit lost by the pest damage is higher than the cost it would take to intervene. (If using an insecticide, costs would include materials and the time spent mixing, loading, and spraying.) Ideally, you would never reach this point, because you would intervene earlier.

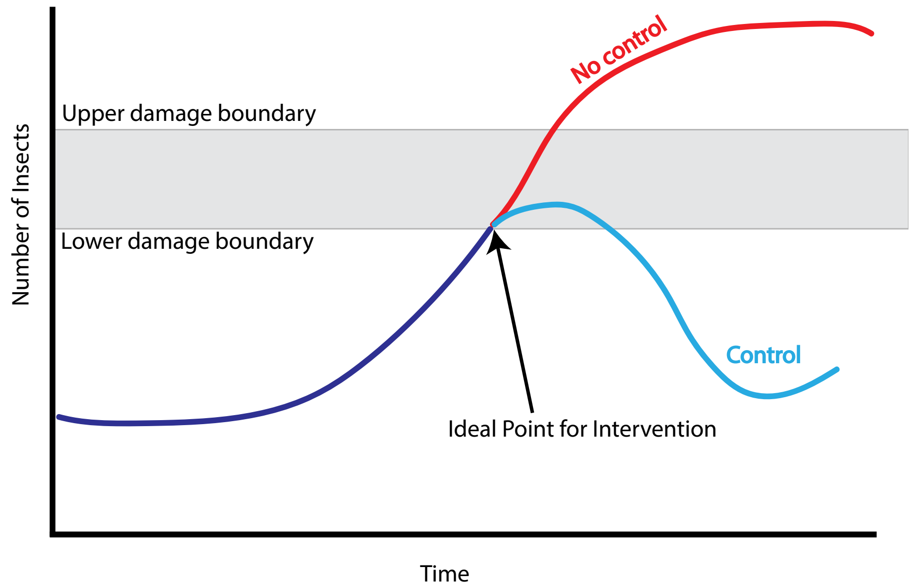

Figure 7. This diagram helps explain intervention timing. The lower damage boundary signifies when intervention should be taken to control the pest population to keep it from reaching the upper damage boundary. If no intervention is made, the pest population will likely go beyond the upper damage boundary. *Source:* Stacy Swartz

The lower damage boundary (economic threshold) is the action threshold. At this point, you will soon face an economic loss if you do not take action quickly. At the lower damage boundary, you need to make a decision about how to control the pest population to keep it from reaching the upper damage boundary.

The upper and lower boundary levels vary from pest to pest and crop to crop. They depend on a number of factors including crop value, location of insect damage, and crop maturity. Crop value, the most important factor, is based on financial profitability and/or the need for the crop as food for the family. Crops that are worth more have lower damage boundaries. Boundaries also vary based on what type of insect is causing the damage and where on the crop it is feeding. For example, fruit trees can generally tolerate higher numbers of insects feeding on the leaves than insects feeding directly on the fruit. Thus, the damage thresholds for fruit trees will typically be lower for insects feeding on the fruits than leaves. The age of the crop also changes the boundaries, since plants typically tolerate more damage at certain growth stages. For example, newly sprouted seeds or small transplants cannot tolerate as much damage as larger, established plants.

The presence of insects that transmit diseases (vectors) also results in lower damage boundaries. The presence of relatively few of these insects can cause significant harm, well beyond damage from feeding. An example of a vector is *Bemisia tabaci*, a whitefly that transmits African cassava mosaic virus.

Conclusion

Integrated pest management is an approach to managing pest control that combines many different and unique intervention strategies. To continuously improve your pest management plan, you need to keep learning about pests, observing pests, and evaluating the effectiveness of your pest control interventions. In the next article in this series, we will describe intervention options. A final article will explain how to evaluate intervention strategies, assess their effectiveness, and make adjustments to future pest management plans.

Further Reading

If you are involved with a plant nursery in the tropics, see the section "Problem Prevention and Holistic Pest Management" in the USDA's publication Tropical Nursery Manual: A guide to Starting and Operating a Nursery for Native and Traditional Plants [http://edn.link/2mtf7j]. The section starts on page 273.

For a facilitator's guide on insect identification and monitoring, see the Canadian Foodgrains Bank's training module on Insect Identification and Monitoring [http://edn.link/9r7z6f].

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From ECHO's Seed Bank: *Apios americana*

by Michelle Boutell

Apios americana is a climbing, perennial vine and a member of the legume (Fabaceae) family. Common names for this crop include apios, ground nut, wild bean, bog potato, wild potato, Virginia potato, Indian potato, and wild bean. The plant, native to eastern parts of North America, was widely cultivated by Native Americans for its edible tubers and beans. It has grown well in the subtropical climate of ECHO's Global Farm in southwest Florida (Sobetski, 2021). Its preference for trellis support makes it more difficult to grow on a field scale than a root crop like cassava (*Manihot esculenta*); however, *A. americana* is well-suited for small plantings around the home, producing protein-rich tubers that can be cooked in multiple ways.

Uses

Many legumes are grown as green manure/cover crops, but *A. americana* is primarily cultivated for its starchy tubers that are an excellent source of carbohydrates and protein (Figure 8; Table 2). *A. americana* roots have more protein than other root crops shown in Table 2, and the protein in *A. americana* roots contains all the amino acids essential to human health (Neacsu *et al.*, 2021).

A. americana tubers contain antinutritional factors [2] and should be cooked before eating. You can boil, fry, or steam the tubers, or cook them other ways that potatoes are typically prepared. The mature beans are also edible; these can be cooked like split peas. Note that some people have reported allergic reactions to consuming *A. americana* tubers and beans (Ecocrop, 2020).

Figure 8. *Apios americana* tubers. *Source:* Holly Sobetski

Table 2. Protein and carbohydrate content of *Apios americana* and three other major root crops. Units of measure are grams (g) per 100 g of dry matter.

Nutritional category	*Apios americana*[Z]	Cassava (*Manihot esculenta*)[Y]	Potato (*Solanum tuberosum*)[Y]	Sweet potato (*Ipomoea batatas*)[Y]
Protein	13-17	3	9	5
Carbohydrate	47	87	67	78

[Z]Data from Kalberer *et al.* (2020) and Walter *et al.* (1986).

[Y]Data from Chandrasekara and Kumar (2016).

The *A. americana* flowers attract butterflies and other pollinators (Figure 9). Additionally, the vines may be used for forage by grazing animals, although hairs on the vines limit their palatability (USDA, n.d.).

[2] An antinutrient is a compound that interferes with the body's ability to absorb nutrients. *A. americana* has trypsin inhibitors, which keep the body from being able to digest protein.

Growing conditions

A. americana thrives in well-drained soils that receive at least 700 mm rainfall annually (Ecocrop, 2020). It has a high tolerance for flooding and a moderate tolerance for shade (Stevens, 2006). Freezing temperatures will kill young plants, so in temperate areas tubers are typically planted after the last frost. *A. americana* can grow between sea level and 1000 m in altitude (Ecocrop, 2020). The plant is not salt tolerant and is most productive in moderate to very fertile soils.

Figure 9. Flowers and foliage of *A. americana. Source:* Holly Sobetski

Cultivation

Once the danger of frost has passed, or at the beginning of the rainy season, plant tubers 5 to 7.5 cm deep. If planting from seed, space seeds 30 cm apart and 2 cm deep in a single row with access to a trellis (Figure 10; Sobetski, 2021). For tuber production, vines can be cultivated with or without trellises. As plants grow, mulch the bases of the plants to retain soil moisture and reduce weed competition.

With tubers planted in April/May, our plants at ECHO's Global Farm in Florida flower in September/October and have full green pods by mid November (Sobetski, 2021). We harvest the roots when the plants die back in late December or early January. Tubers will be sweeter with cold weather. Tuber production has been shown to respond well to added fertility (Putnam *et al.*, 1991). Harvest the tubers when the plants' leaves begin to turn yellow and die back. Propagating plants

Figure 10. *A. americana* plants grown on a wire trellis. *Source:* Holly Sobetski

from tubers will result in plants with traits identical to the parent plants. Plants grown from seed, on the other hand, will not have the exact same characteristics as the parent plants, due to the mixing of pollen--and, thus, genetic information--between plants. Planting *A. americana* from seed presents an opportunity to select for plants that grow and produce well under local conditions.

Seeds from ECHO

Active development workers who are members on ECHOcommunity.org may request a trial packet of seed. (See the website for how to register as a member and how to order seeds.)

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Echoes from our Network: Subscribe to ECHO Asia Notes!

by Patrick Trail

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Readers of *ECHO Asia Notes* can enjoy articles such as Anthony Wong's summary of an innovative Black Soldier Fly System at the Frangipani Langkawi Organic Farm [http://edn.link/34xyjq] in Malaysia, or a collection of Livestock Feed Formulations from the Aloha House Farm [http://edn.link/ex7pwk] in Palawan, Philippines.

In addition to articles from the ECHO Asia network, we include updates from the ECHO Asia Small Farm Resource Center & Seed Bank. Examples include a guide on Grafting Tomatoes to Local Eggplant Rootstock [http://edn.link/hakx3p] and summaries of ECHO's recent research making On-Farm Feeds for Pigs, Poultry, and Fish [http://edn.link/q3mcc9].

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Books, Websites, and Other Resources: Review of Agroforestry Design Tool™

by Tim Watkins

The Permanent Agriculture Resources and Forest Agriculture Research Management Center, led by Craig Elevitch, recently released their Agroforestry Design Tool™ for Beta testing and held a series of webinars [http://edn.link/qffwe4] guiding users through the tool. Elevitch has been a longtime advocate for agroforestry as director of Agroforestry Net, has authored multiple books and resources on agroforestry in the Pacific Islands, and serves as editor of *The Overstory*, a monthly journal dedicated to agroforestry. The online Agroforestry Design Tool™ allows users to rapidly generate complex agroforestry planting arrangements and visualize how these planting arrangements are likely to develop over time. Most of the planting patterns draw from traditional Pacific Island agroforestry systems or simplifications of those planting arrangements. Users can easily create an account, enter climate and soil parameters for their site (to filter out inappropriate crops), then select a planting arrangement and desired crops. The tool categorizes crops based on the particular stratum (layer of the canopy) that each occupies within the system, and on each crop's permanence. An important feature of the design tool is the ability to select *medium-term* crops that will yield food for the first several years (1-4) as the agroforest is developing. At year 4, those medium-term crops are removed from the system to allow more space and resources for the long-term crops to develop.

The Agroforestry Design Tool™ generates two-dimensional visualizations of your agroforestry planting at years 3 and 10. These visualizations help project the canopy development and potential interactions of the crops as the system matures. A unique feature of the tool is the animation generator that allows you to view the development of your design over a 15-year period, including the removal of the medium-term crops and fluctuations in tree canopy based on the pruning parameters that you chose. The animations visually represent the expected growth and development, canopy density, and plant succession within the system over a 15-year period. Lastly, the tool generates a PDF report that includes the initial planting layout/diagram; 3- and 10-year visualizations of spatial arrangement of crops; crop lists; and overhead and side views of the planting arrangement.

In the online tool, hovering your cursor over a plant will display the common and scientific name. However, the report does not have labels for individual plants. You would need to write the names into the planting diagram or create a simple code for the different plants and use that to label plants in the diagram. While some plant species available for use in the design tool are unique to the Pacific Island region, most are appropriate for agroforestry systems throughout the humid and subhumid tropics. Also, several generic plant profiles can be selected to represent species not available in the tool's plant database. The designers plan to expand the species selection tool and add additional planting patterns to fit other regions, especially drier climates and temperate regions.

Overall, the Agroforestry Design Tool™ provides a simple, efficient way to generate complex agroforestry planting arrangements using a diverse suite of tropical fruits, nuts, timber trees, perennial vegetables, vines, and root crops. The visualizations and animations add a unique dimension, allowing you to "see the future" of your design and to modify it so you can maximize the potential for production and minimize negative tree-crop interactions (such as competition). A Beta version is free on the AgroforestryX website (https://www.agroforestryx.com/). Elevitch and his team would appreciate any feedback you might have as they continue to improve and develop this unique tool.

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Elevitch, C.R., and N. Logan. 2019–2021. Agroforestry Design Tool™–AgroforestryX.com. Hawaii. agroforestryx.com.

Upcoming Events

ECHO East Africa Event

Virtual ECHO East Africa Symposium on Sustainable Agriculture and Appropriate Technologies

ONLINE EVENT
September 28-30, 2021

ECHO Florida Event

ECHO's 28th Annual International Agriculture Conference

ECHO's Global Farm in Florida, USA
November 16-18, 2021